Parameter Trade Studies For Coherent Lidar Wind Measurements of Wind from Space

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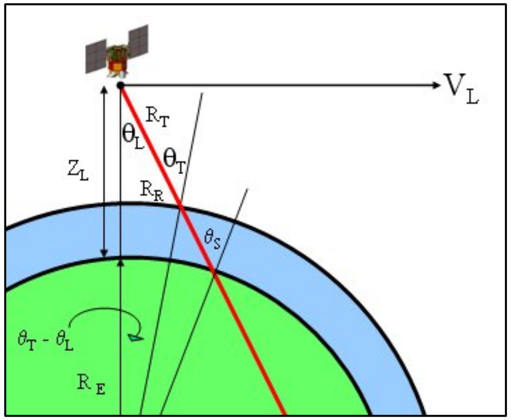
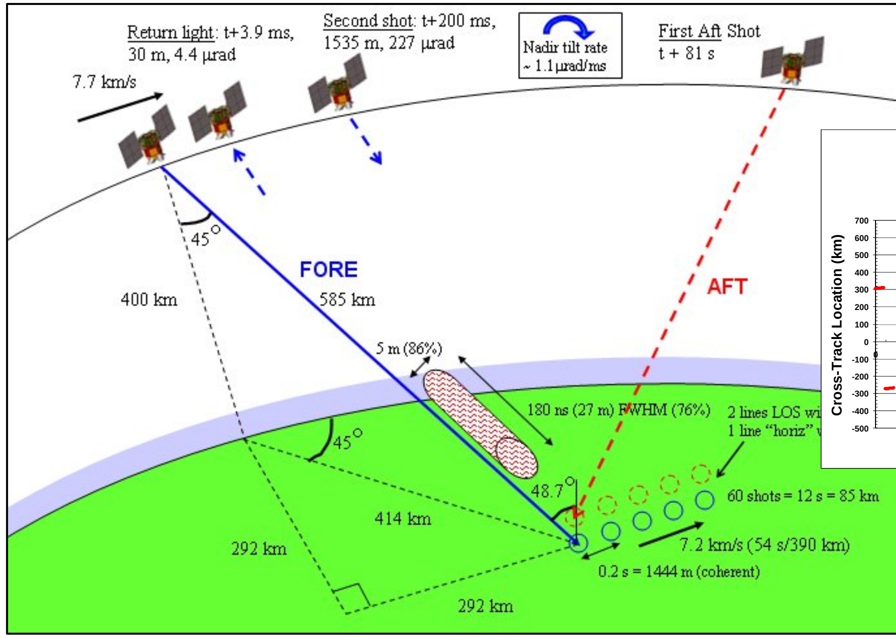
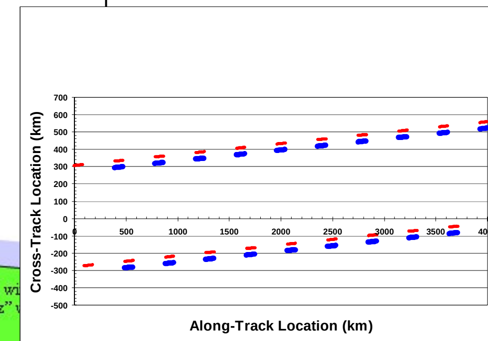
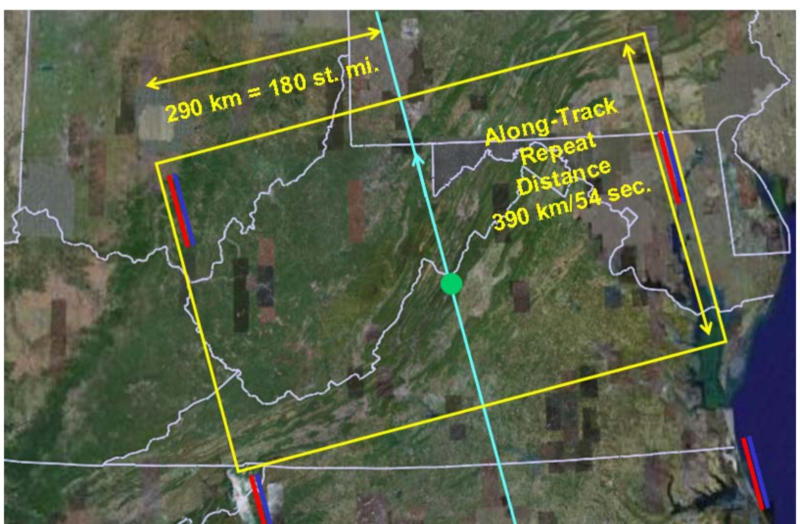
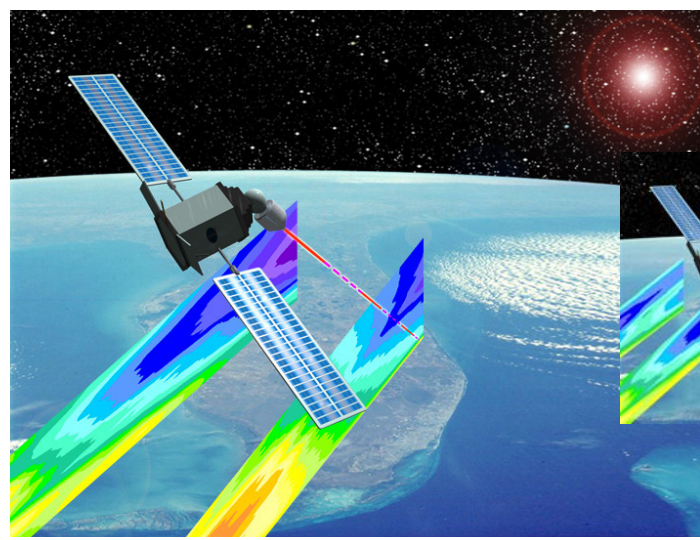
Global Wind Mission Concept

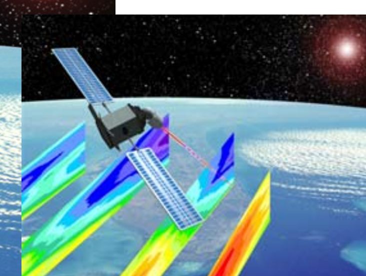










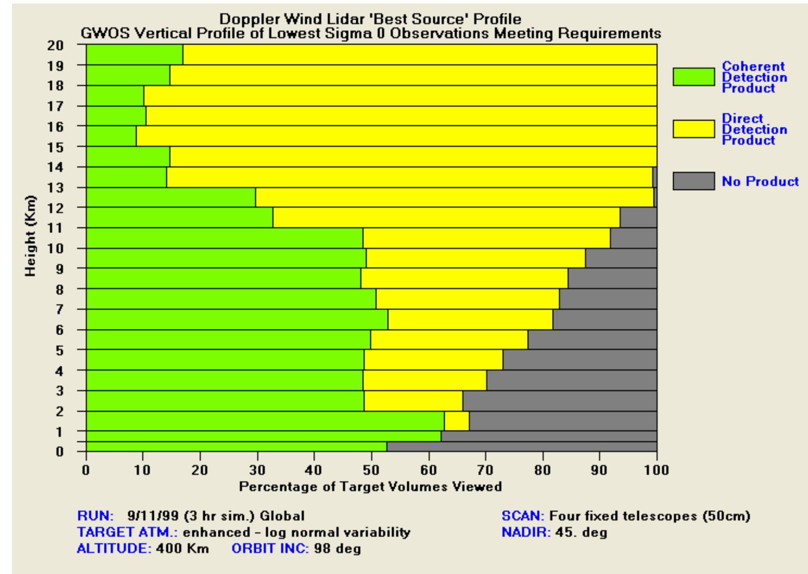


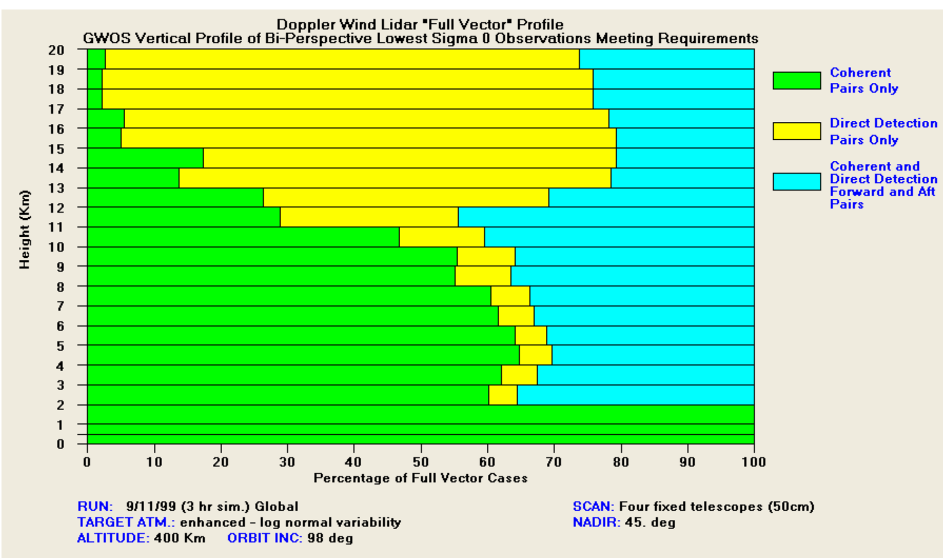
Hybrid Doppler Lidar Concept

Complementary Lidars Together Lower Total Mass, Power, Cost, Risk

<u>Green</u> represents percentage of sampled volumes when coherent subsystem provides the most accurate LOS measurement; **<u>Yellow</u>** is for direct detection; **<u>Gray</u>** is when neither system provides an observation that meets data requirements

GWOS with enhanced aerosol mode





When two perspectives are possible

<u>Green:</u> both perspectives from coherent system

<u>Yellow:</u> both perspectives from direct molecular

<u>Blue:</u> one perspective coherent, one perspective direct

GWOS Mission Study

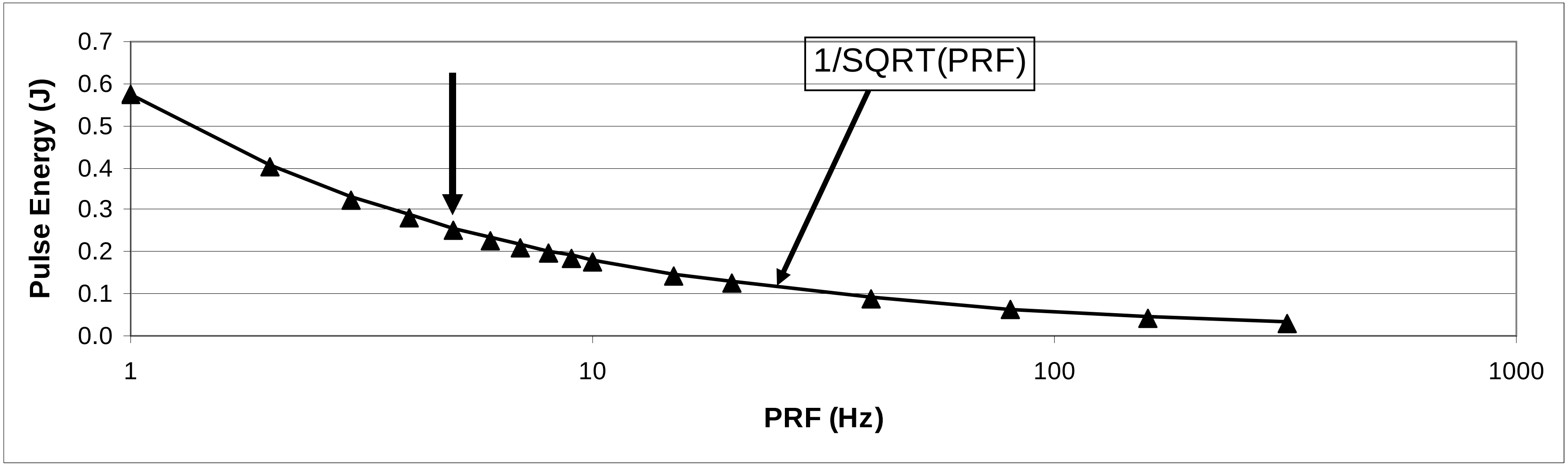
- Hybrid Doppler lidar
- 400 km, 45 deg nadir, 4 azimuth angles
- Coherent lidar:
    - 0.25 J, 5 Hz, 2.053 microns, 180 ns
    - 0.5 m receiver diameter
    - 60 shot accumulation attempted; 12 s; 85.2 km
    - Pattern repeat = 4 x (12 + 1.5) = 54 s = 390 km
- 1 m/s design 1-σ wind turbulence (broadens sig. spectrum)
- 0.5 m/s 1-s laser difference frequency knowledge error
- No vertical shear of horizontal wind velocity (always aligned with beam: broadens signal spectrum)
- Sampling/representativeness error = 0.62 m/s (85 km line in 100 km box)

Specific GWOS Operating Point For Trade Studies

- 5 km altitude wind measurement height
- Enhanced aerosol levels; $\beta = 2.75 \times 10^{-8}\ m^{-1}sr^{-1}$
- Vertical resolution = 2000 m
- $\varphi = 4.5$ (# coherent photoelectrons per range gate per shot)
- 60 shots accumulation attempt
- Pr{good} = 0.95
- Lidar LOS velocity error = 1.5 m/s
- Lidar horizontal velocity error = 2.0 m/s
- With sampling error, total horizontal velocity error = 2.1 m/s

Pulse Energy vs. PRF

- Hold Pr{good} = 0.95
- Velocity error does not change

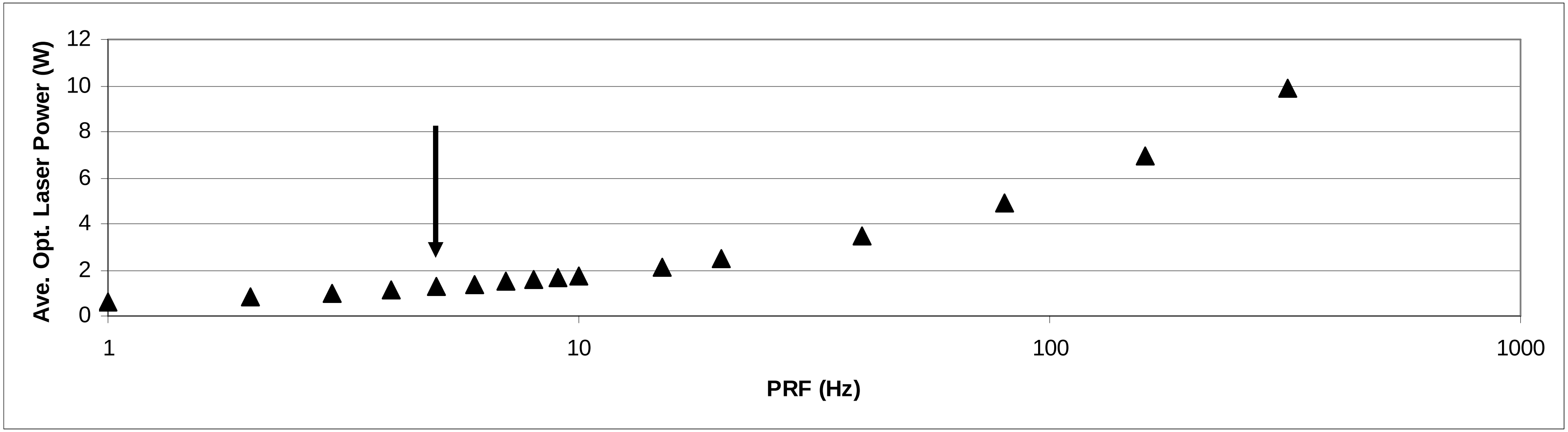


Favors higher PRF?

nominal operating point

Laser Power vs. PRF

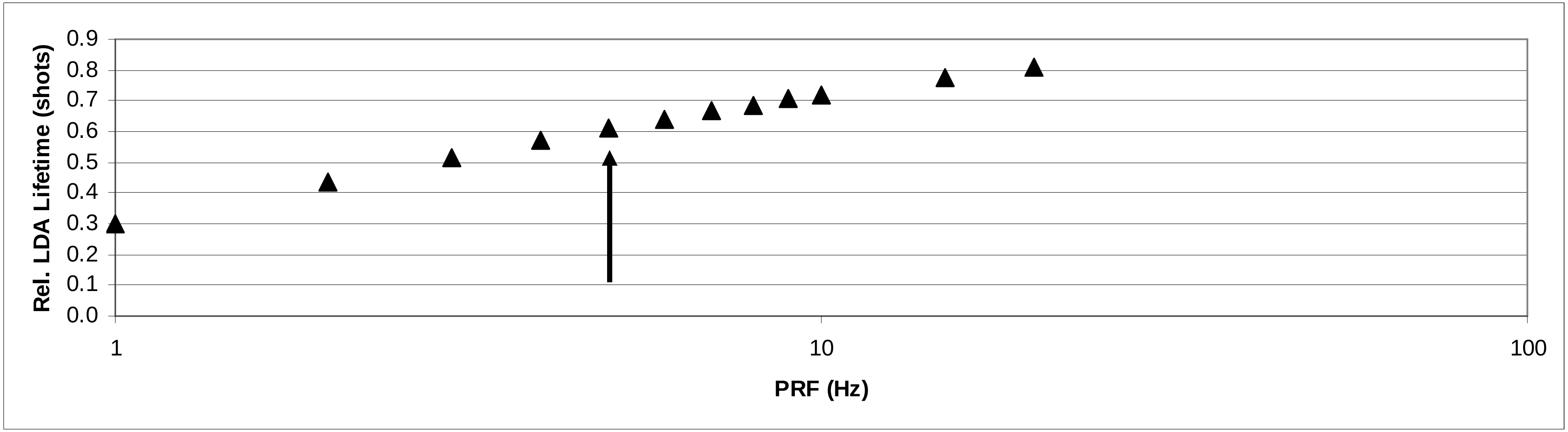
- Hold Pr{good} = 0.95
- Velocity error does not change
- Laser Power = Energy x PRF



Favors lower PRF?

Relative LDA Lifetime vs. PRF

- Hold Pr{good} = 0.95
- Velocity error does not change
- LDA lifetime probably reflects laser lifetime

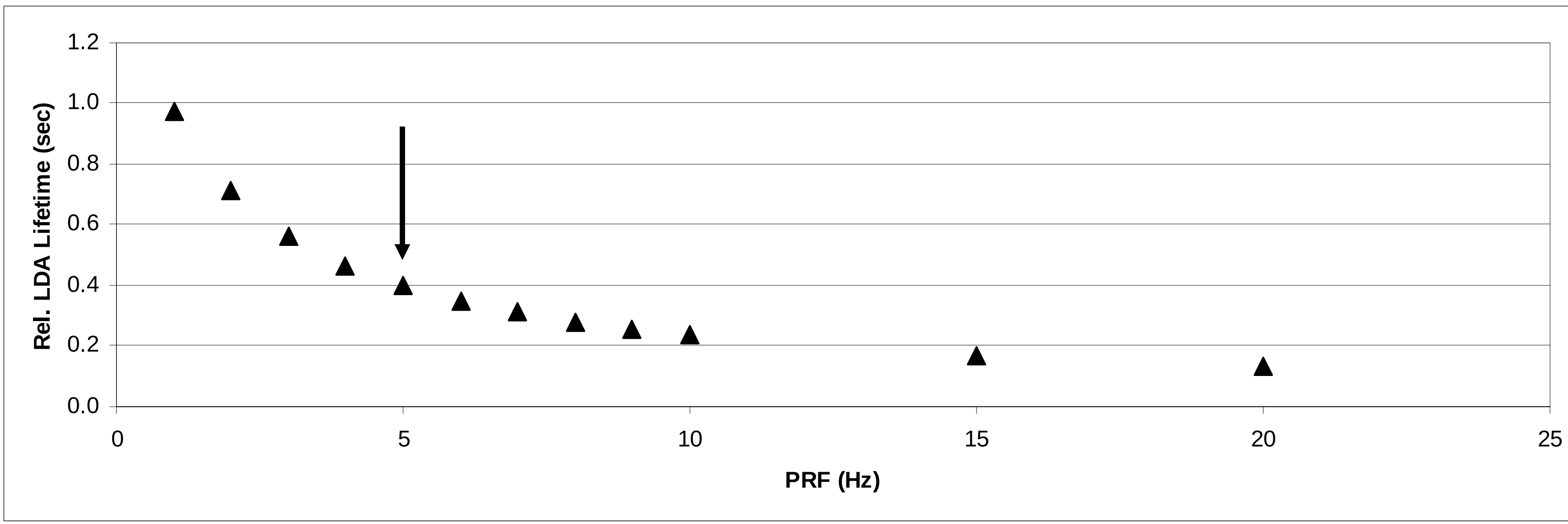


Favors higher PRF?

PRF vs. LDA Lifetime

PRELIMINARY FOR TRADE CONCEPT ONLY

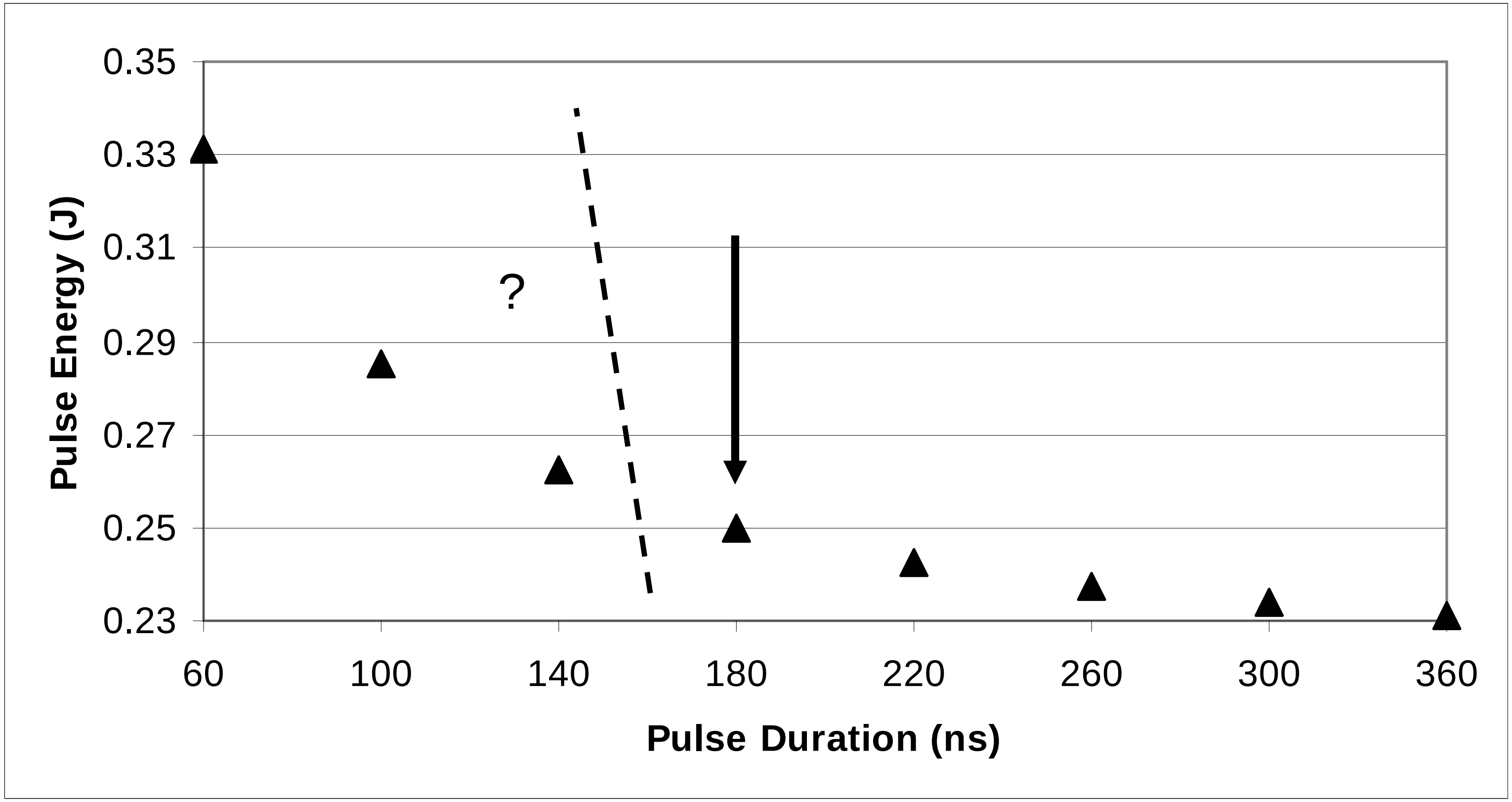
- Hold Pr{good} = 0.95
- Velocity error does not change
- Lifetime in **seconds** more important than lifetime in shots
  (seconds = shots/PRF)



Favors lower PRF?

Pulse Energy vs. Pulse Duration

- Hold Pr{good} = 0.95
- Velocity error fairly constant above 180 ns (5% bad estimates dominating)

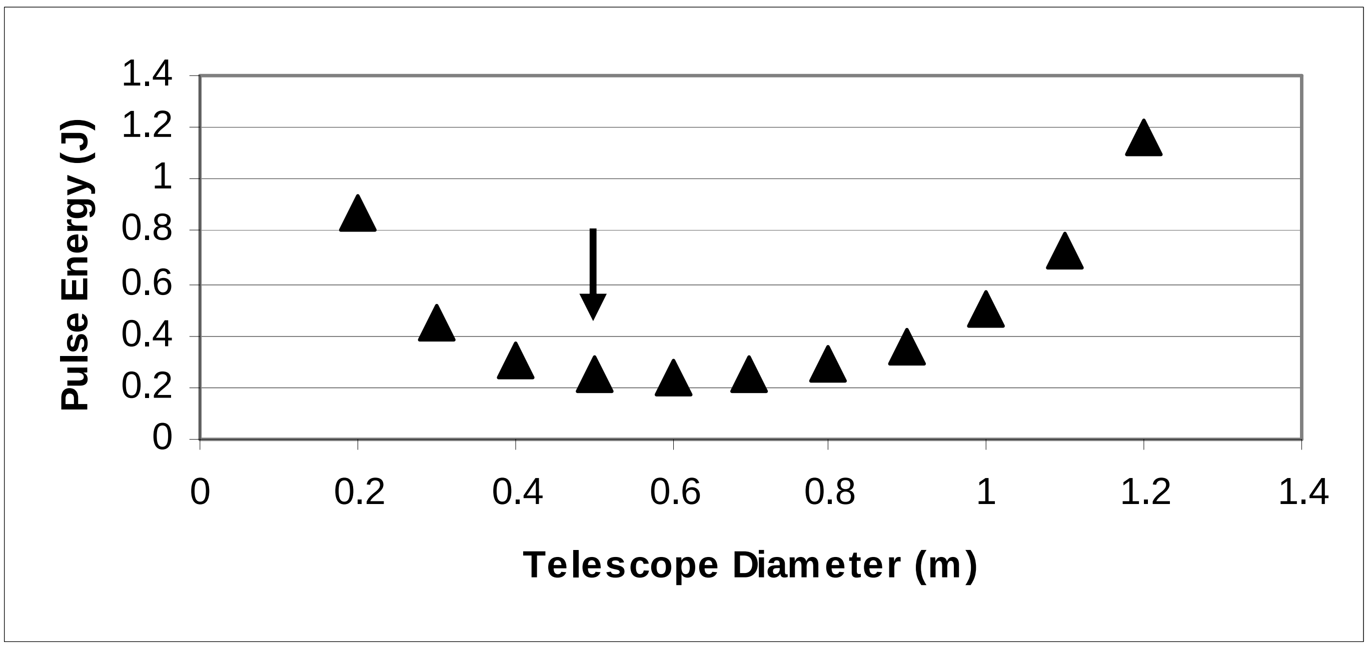


?

Outside the validated parameter range of the performance parameterization

Pulse Energy vs. Telescope Diameter

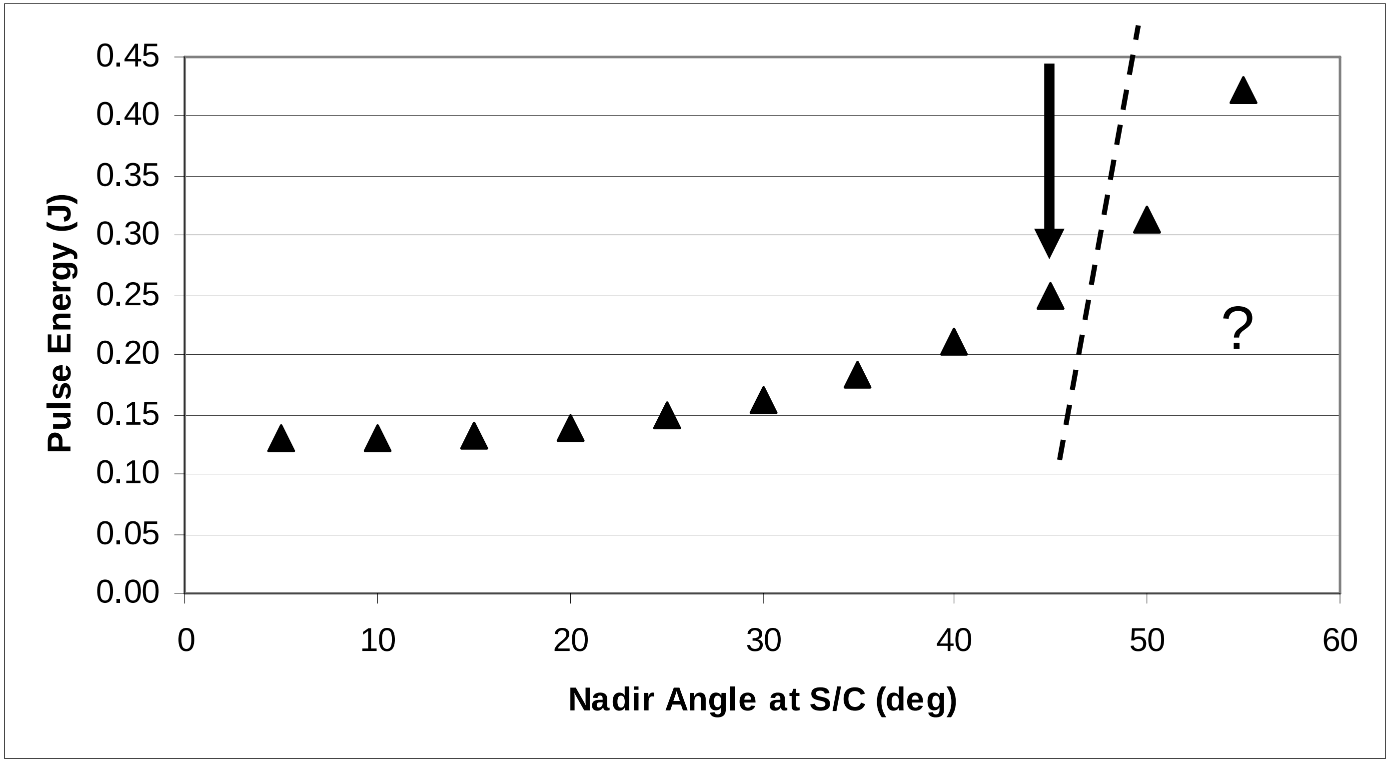
- Assume scanner does not reduce collection area
- Assume 1-σ transmit/receive misalignment angle fixed at 3.082 μrad
- Hold Pr{good} = 0.95 <u>and</u> velocity accuracy constant



- Larger diameters have more SNR loss for fixed misalignment angle

Pulse Energy vs. Nadir Angle

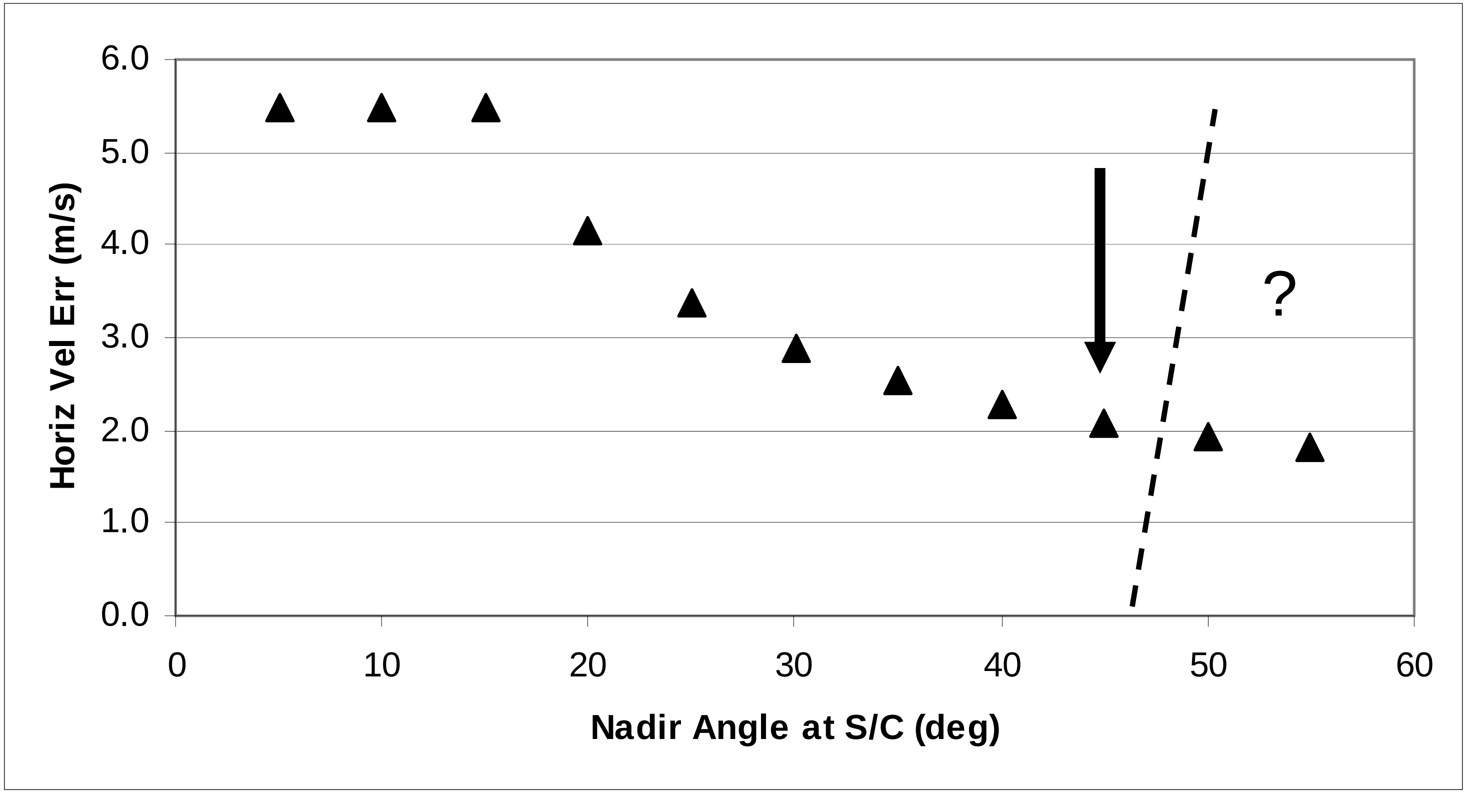
- Hold Pr{good} = 0.95
- Above 70 degrees misses the earth



- Spherical earth steepens the slope

Velocity Error vs. Nadir Angle

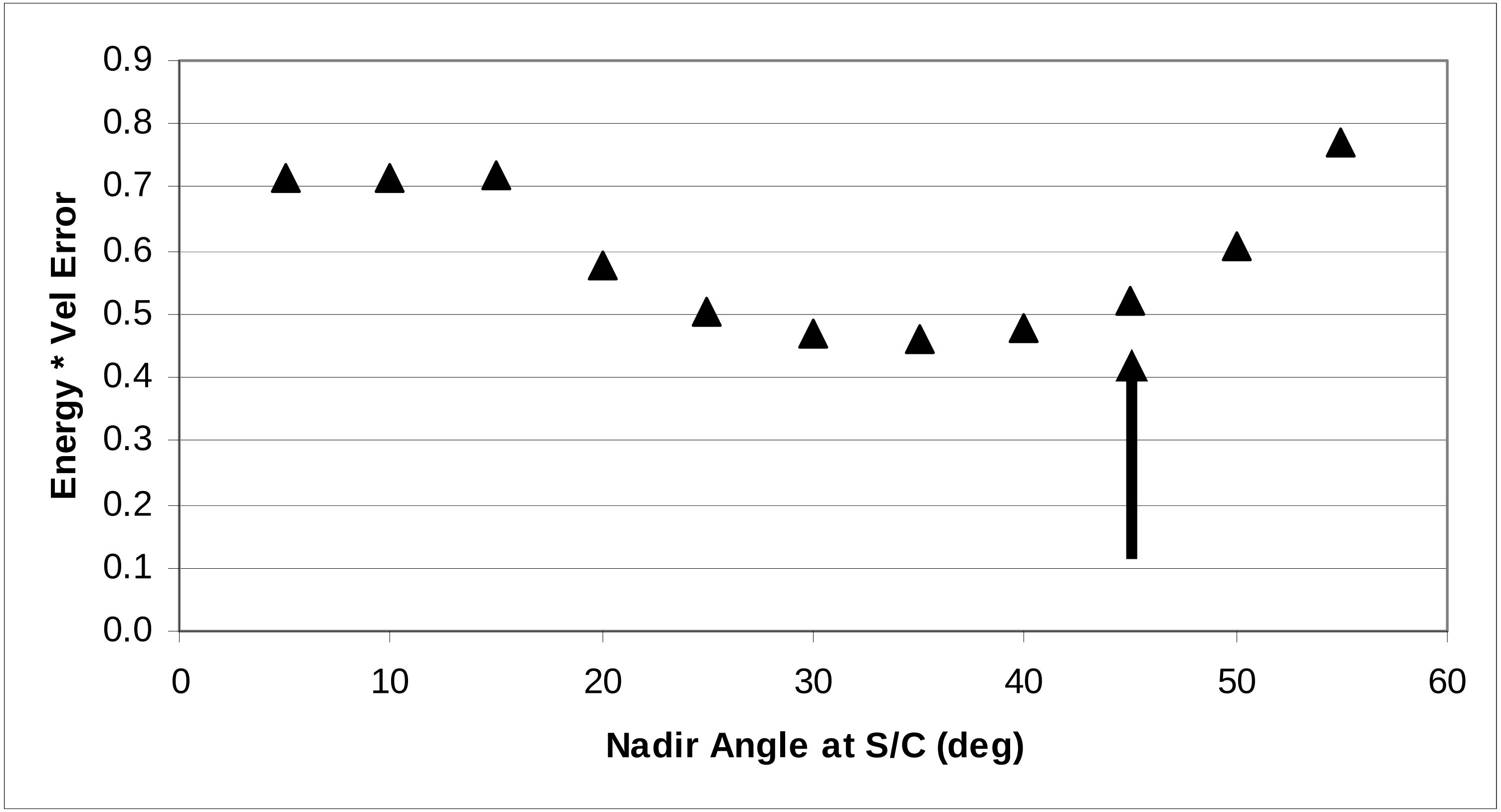
- Hold Pr{good} = 0.95
- Above 70 degrees misses the earth



- Laser beam more horizontal at larger nadir angles

Velocity Error x Pulse Energy vs. Nadir Angle

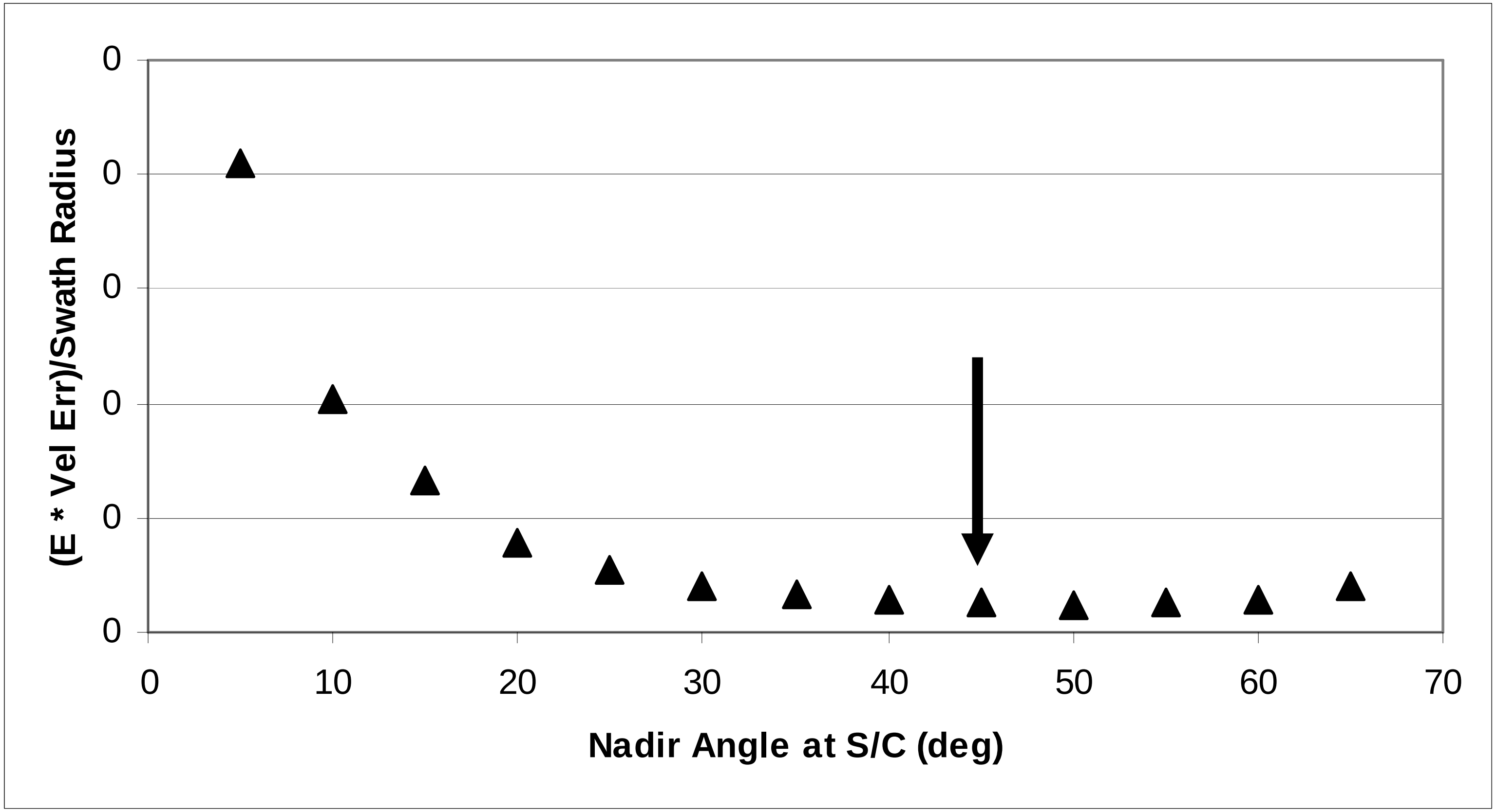
- Hold Pr{good} = 0.95
- Above 70 degrees misses the earth



- Broad optimum from 25 – 45 degrees

(Error x Energy)/Swath Radius vs. Nadir Angle

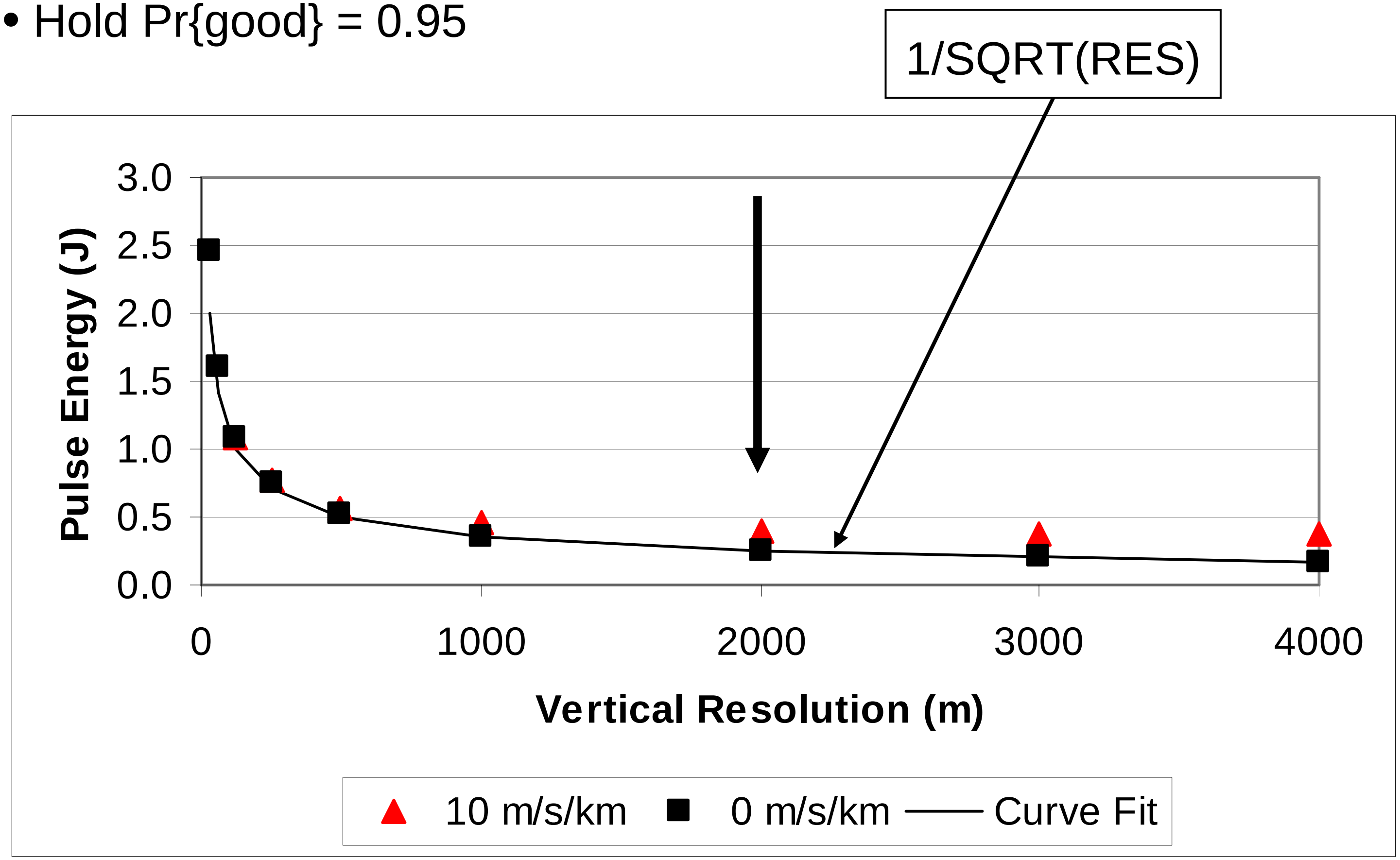
- Hold Pr{good} = 0.95
- Above 70 degrees misses the earth



- Broader optimum; what other figures of merit are there?

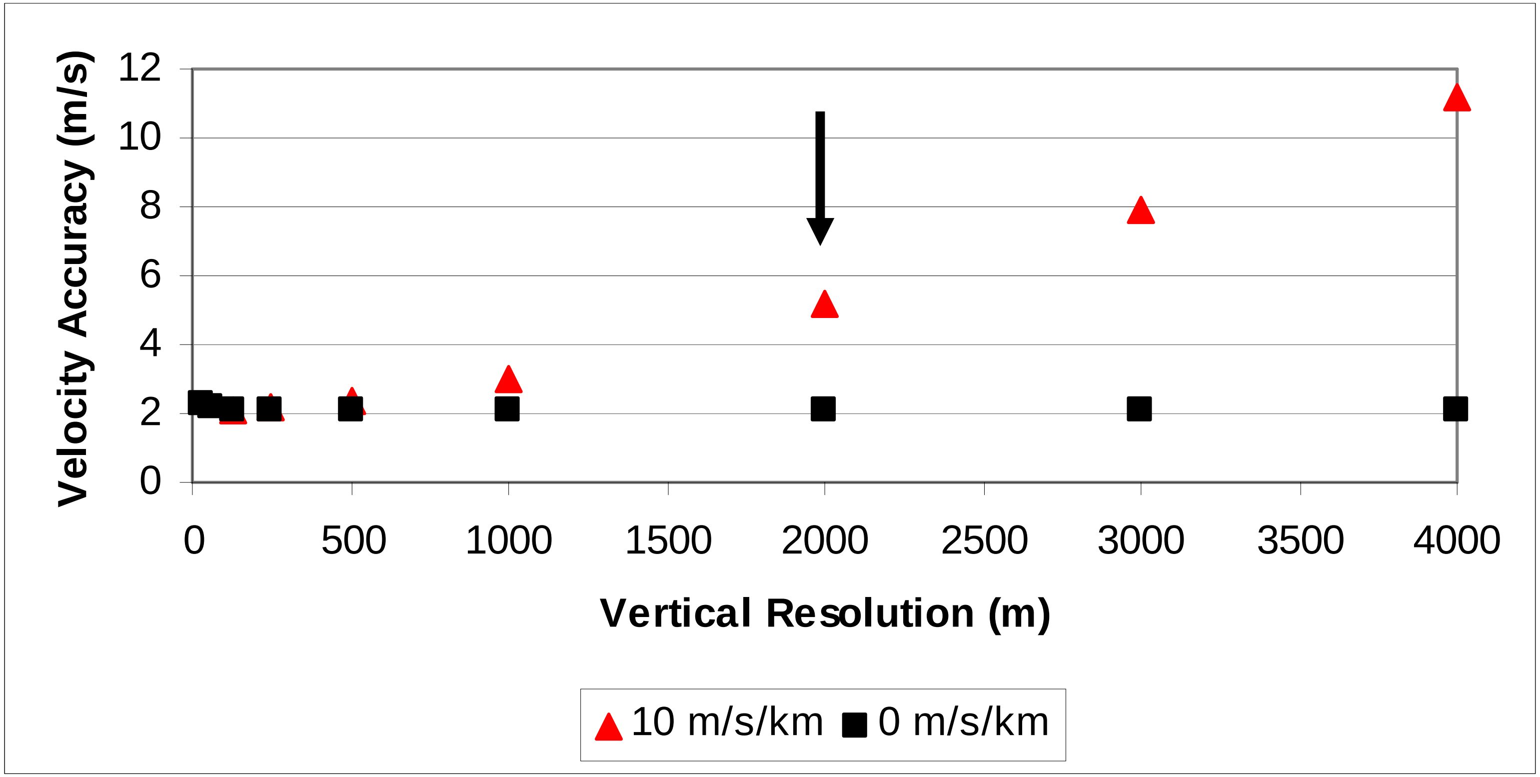
Pulse Energy vs. Vertical Resolution

- Hold Pr{good} = 0.95



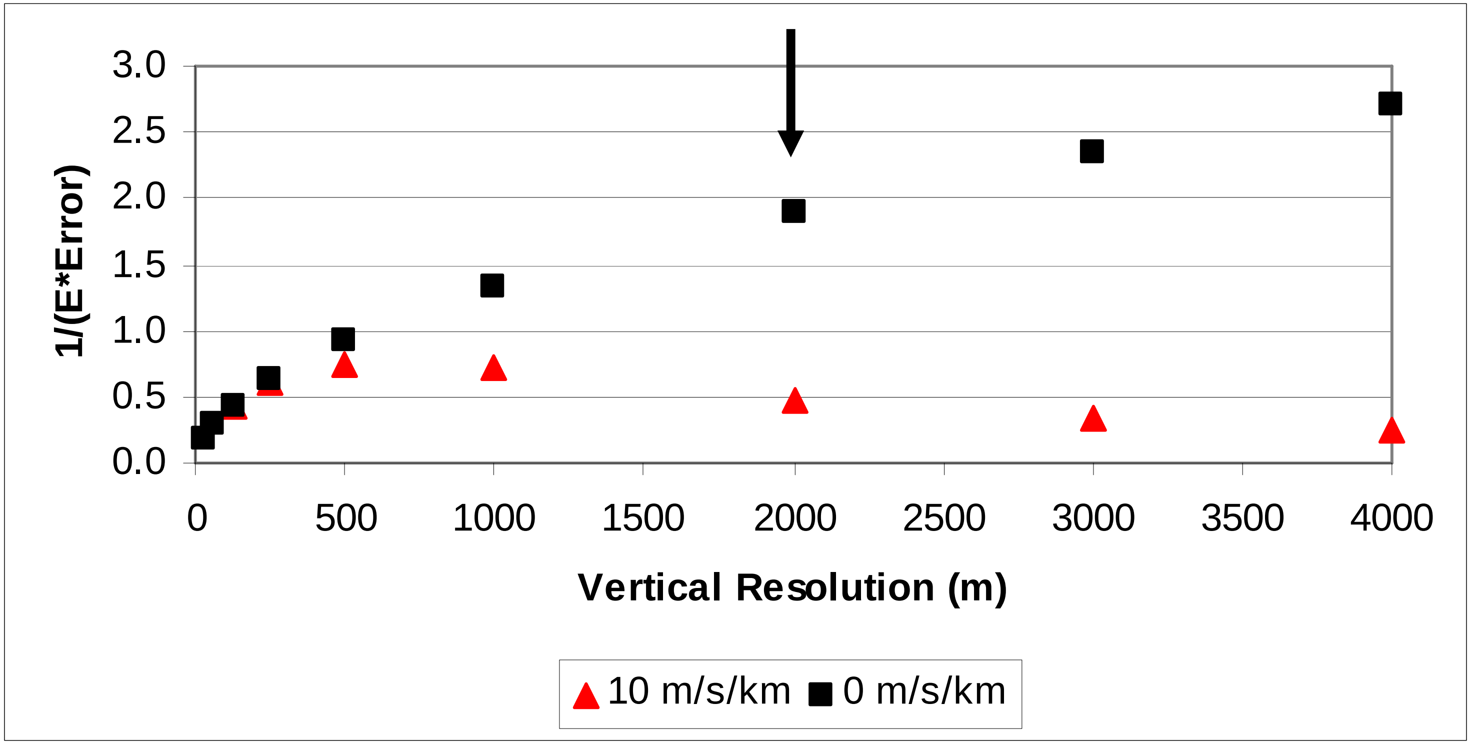
- Wind shear increases required pulse energy

Velocity Accuracy vs. Vertical Resolution



- Wind shear greatly increases velocity error
- Dilemma: pulse energy and velocity error favor oppositely

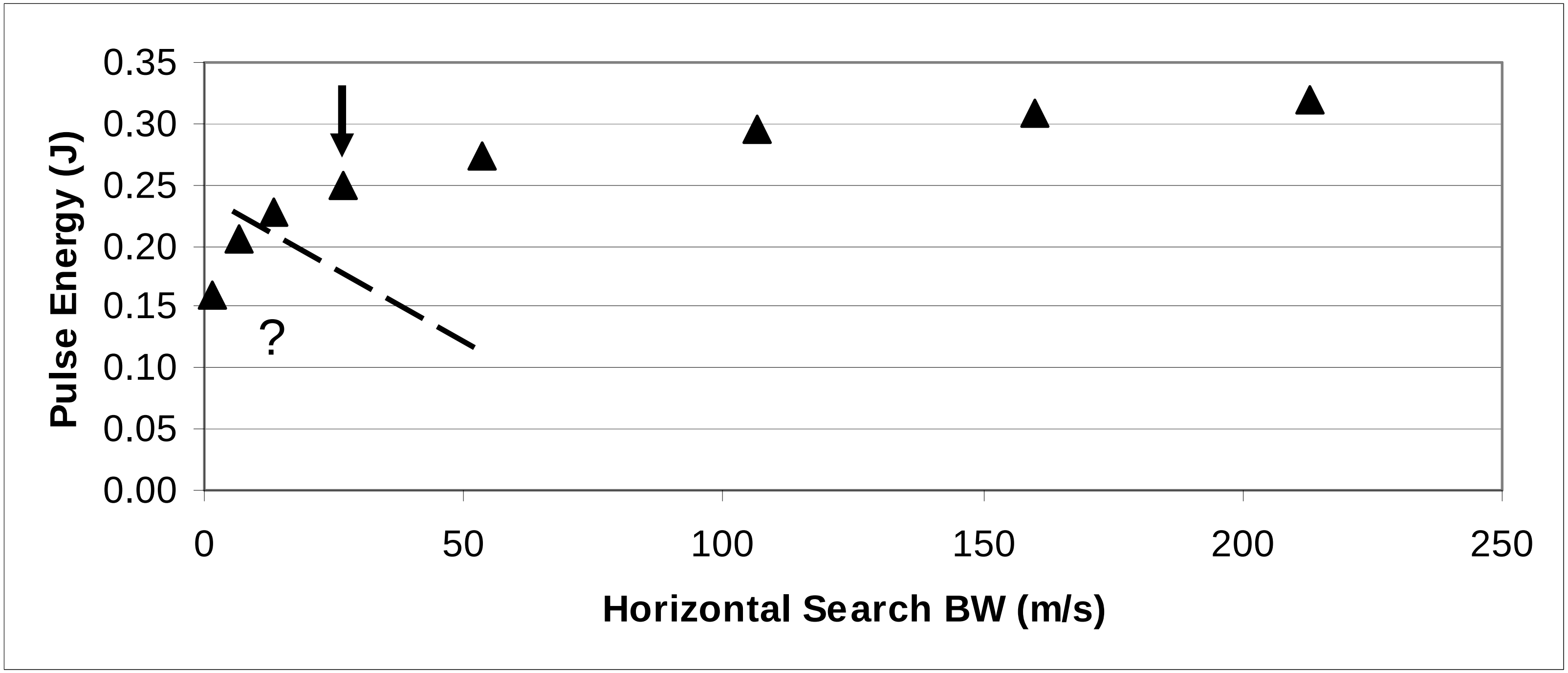
(Energy x Error)$^{-1}$ vs. Vertical Resolution



• Wind shear case has optimum vertical resolution

Pulse Energy vs. Velocity Search Bandwidth

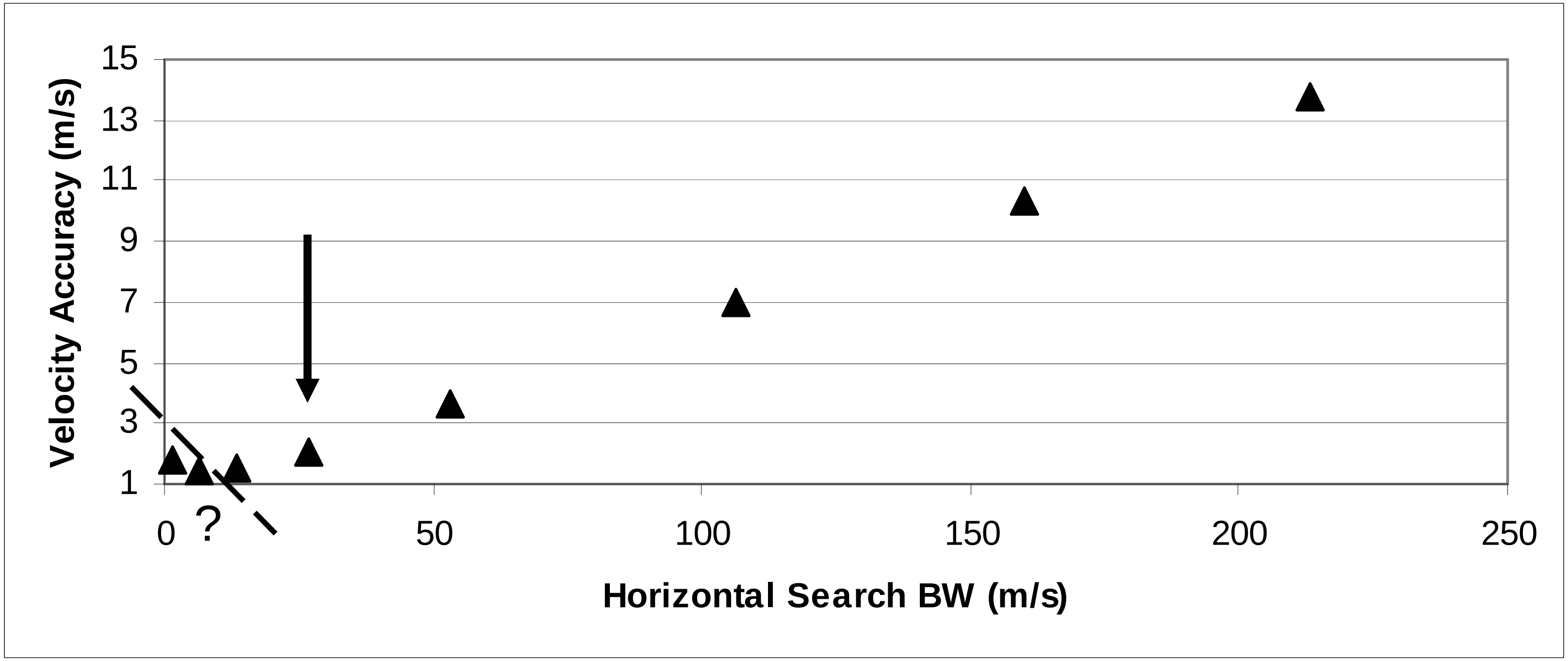
- Full search bandwidth in horizontal direction for last pass through the data
- Hold Pr{good} = 0.95



- Significant effect on pulse energy

Velocity Accuracy vs. Velocity Search Bandwidth

- Full search bandwidth in horizontal direction for last pass through the data
- Hold Pr{good} = 0.95



- Large effect on velocity error
- Bad wind estimates dominate error

Summary and Conclusions

- NASA LaRC computer simulation of global wind profiling coherent-detection Doppler lidar uses latest published theory
- Simulation permits parametric trade studies with choice of parameters held constant
- Tool should prove useful in mission design and guide to parameter goals for technology under development
- There are many more possible trades than are shown here
- Desire to incorporate optic component aberrations, laser beam intensity and phase description, and misalignment rigorously into theory

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